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Surface Warfare Threat Assessment: Requirements Definition

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ADMINISTRATIVE INFORMATION

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EXECUTIVE SUMMARY

This report discusses the results of a preliminary investigation of cues (e.g., speed, range, etc.) that experienced surface warfare personnel use to assess the threat level of nearby surface ships. Data were collected from experienced U.S. Navy surface warfare watch standers within a Combat Information Center (CIC) on an Aegis-equipped ship. The data were incorporated into an outline of an algorithm for surface threat assessment. The objectives of this investigation were as follows:

- Find the level of threat associated with different types of ships
- Describe the relationship between specific values of cues and the corresponding perception of threat
- Rank cues in order of importance or relevance to threat assessment
- Find the flow of information in CIC
- Develop an algorithm for preliminary surface threat assessment

RESEARCH BACKGROUND

The data collection and algorithm development followed the same process that Liebhaber and Smith (2000) and Liebhaber, Kobus, and Smith (2000) used to provide theoretical and applied basis for air threat assessment. In these studies, participants described a list of 18 cues (aircraft characteristics) relevant to the threat assessment process. This report discusses a similar list developed for evaluating surface threats. This work developed from research on Decision Support Systems (DSSs) in the Tactical Decision-Making Under Stress (TADMUS) program. DSS supports the cognitive strategies of tactical decision-makers operating in highly complex, fast-paced littoral environments. While the DSS was successful, theoretical and applied investigation of the threat assessment concepts was minimal. This report discusses the initial efforts toward understanding the surface warfare aspects of the threat assessment process.

FINDINGS

Nine surface-warfare-experienced participants provided baseline threat ratings for ship categories (e.g., Friend, Combatant, Oiler, etc.) and the relationship between perceived threat rating and specific cues (e.g., speed of 10 to 15 knots = raise threat rating a little). Baseline threat ratings were consistent with the findings from air defense studies (Liebhaber and Smith, 2000; Liebhaber, Kobus, and Smith, 2000). Participants also ranked the importance or relevance of each assessment cue and described the flow of surface warfare information. The top three cues, tied for number one, were Platform Type, Weapon Envelope, and Electronic Emissions. Flow data provided an understanding of the information requirements and functional relationships within CIC.

SURFACE THREAT ALGORITHM

Data were incorporated into a rule-based, surface threat algorithm. The air threat algorithm (Liebhaber, 2001) provided a procedural framework for the surface algorithm. The algorithm analyzes relevant data and computes a threat rating for a surface track.

RECOMMENDATIONS

Surface warfare data were collected from highly experienced U.S. Navy personnel. The data provide a foundation for the development of a working algorithm. However, the next phase of investigation should include an empirical determination of cue use patterns and cue weights. Those findings can then be incorporated into future development of the algorithm for surface warfare threat assessment and interface guidelines.

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1. INTRODUCTION

The Surface Warfare Threat Assessment project had two major goals:

1. Identify information that experienced surface warfare (SUW) personnel use in assessing the threat level of nearby surface craft.

2. Develop an algorithm for preliminary surface threat assessment.

To reach these goals, a knowledge engineering study identified the specific assessment cues that individuals and expert tactical decision-makers use on a ship's Combat Information Center (CIC). Data were also collected on the relationship between the perceived threat rating of surface ships and the specific cues (e.g., speed over 15 knots). This report discusses study results and outlines a preliminary surface threat algorithm.

Surface ship threat assessment involves evaluating cues from tracks (radar contacts) to identify and assess threats to the ship or battle group. Cues (also called data, features, or attributes) are characteristics associated with tracks such as origin, speed, and range. No one system or person on the ship provides conclusive identification or threat assessment. An interaction between sensor systems, computers, and human operators within the CIC produces these tasks. The tasks need a team of highly trained people to evaluate, integrate, and judge information.

When warfighters have a poor understanding of the tactical situation, they may rank threats inaccurately and share tactical resources inadequately. Current systems produce tactical pictures that can be incomplete, misleading, hard to interpret, and untimely. Adequate decision support systems (DSSs) must allow warfighters to manage information quickly, tailor it for mission requirements, and help them tactically grasp mission-critical information. The research reported here is one part of a research program that will meet those requirements. This program focused on the following goals:

1. Determine the information that expert tactical decision-makers use in evaluating potential threat tracks in ambiguous operational situations

2. Build an executable model of threat assessment for a decision-support tool

3. Validate the decision-support tool(s) in operation

This effort will produce tools that help tactical warfighters assess contacts, rank contacts in their degree of threat, and develop appropriate courses of action to reduce threat uncertainty, which will increase tactical awareness.

The specific objectives of this study were as follows:

1. Find the level of threat associated with different types of ships

2. Describe the relationship between specific values of cues and the corresponding perception of threat

3. Rank cues in order of importance or relevance to threat assessment

4. Find the flow of information in CIC

5. Develop an algorithm for preliminary surface threat assessment

Data collection and development followed the same process used for developing an air defense algorithm (Liebhaber, 2001). Liebhaber and Smith (2000) and Liebhaber, Kobus, and Smith (2000) provided a cognitive basis for the algorithm. They investigated the practice of threat assessment within U.S. Navy single-ship air defense. The studies provided answers to questions such as the following: What information do air defense personnel use to assess aircraft contacts and do they use it systematically? In these studies, participants listed 18 cues (aircraft characteristics) relevant to the threat assessment process. A similar list was developed for evaluating surface threats from the results of this study.

This work developed from research on DSSs in the Tactical Decision-Making Under Stress (TADMUS) program. TADMUS focused on evaluating DSS display concepts derived from cognitive theory, most notably, Naturalistic Decision-Making (Zsambok and Klein,1997). DSS supports the cognitive strategies of tactical decision-makers operating in highly complex, fast-paced littoral environments. See Hutchins (1996), Rummel (1995), and Morrison (2000) for reviews of DSS. One TADMUS DSS component was called the Basis for Assessment (BFA) tool. The tool was a display section with explanation-based threat assessment. System operators could view a detailed list of evidence for and against the current assessment of the selected track. Pennington and Hastie (1988) described a similar display. The tool reduces the likelihood of mis-categorizing and engaging friendly or neutral tracks (Morrison et al., 1997). DSS was successful, but the threat assessment concepts were investigated further. Liebhaber and Smith (2000) and Liebhaber, Kobus, and Smith (2000) initiated studies to better understand the threat assessment process in air warfare and to develop better algorithms and displays. This report discusses the initial efforts toward understanding the threat assessment process for surface warfare.

2. METHOD

A questionnaire gathered data on the information that SUW personnel use to assess the threat level of surface craft within their ship's surveillance area. Appendix A includes the questionnaire.

2.1 PARTICIPANTS

Nine U.S. Navy personnel with at-sea experience in SUW participated in this study. They had a mean of 7.9 years (SD = 4.8 years; Range = 3.7 to 12.1 years) of at-sea experience in CIC. They were experienced in an average of 3.3 (SD = 1.3) CIC watch stations. Their experience included an average of 3.4 years as the SUW Coordinator, the focal point of Anti-Surface Warfare in CIC. Appendix B describes the participants' CIC watch station experience.

2.2 QUESTIONNAIRE

Items on the questionnaire were developed from U.S. Navy documents and with current and former SUW personnel. The questionnaire's first page gathered data regarding each participant's SUW experience. The rest of the questionnaire was divided into four parts.

Part 1

The first set of questions identified baseline threat levels for Flag (ID or Origin; indicates the country from which the track most likely originated) classifications (e.g., Unknown, Neutral, Enemy, etc.) and different type of ships (e.g., Combatant, Patrol, Cargo, etc.). Threat was defined as the perceived ability of a track to inflict damage on one's own ship or battle group. It pertained only to the degree of the threat posed by a particular track. Participants were asked to respond for two operational environments: littoral (near shore) and open ocean. Earlier work (Liebhaber and Smith, 2000) found differences in threat levels for each environment. Participants responded on a 5-point Likert scale (range from 1 = Never Threatening to 5 = Always Threatening). Table 1 is an example for the question: "How threatening, on average, is this type of ship? (Please circle your response)".

Table 1. Threat level response example.

Military Ships	Never	Rarely	Sometimes	Often	Always
Carrier	1	2	3	4	5
Surface Combatant	1	2	3	4	5
Patrol/Escort	1	2	3	4	5
Oiler	1	2	3	4	5
Sealift	1	2	3	4	5

Part 2

Participants estimated change to baseline threat level for 15 cues. Appendix C lists the cues with definitions. Each cue lists data values, as shown below for *Range*. Transcripts of verbal protocols in Liebhaber and Smith (2000) and from SUW subject matter experts determined the data values. Participants were instructed to treat each cue (e.g., Range) as the first piece of data received, and then to indicate how that data would change their estimate of threat. They were told to answer based on their at-sea experience. All questions were about single pieces of information (e.g., speed, range, heading, etc.). Although information is not processed in isolation in the real situation, our goal was to understand how participants evaluated individual elements. Participants responded on a scale from 1 (lower threat level greatly) to 5 (raise threat level greatly). Table 2 shows an example of data and response values for Range are shown below.

Table 2. Range data and response values.

Range	Lower Greatly	Lower a Little	No Change	Raise a Little	Raise Greatly
Under 5 nmi	1	2	3	4	5
5 to 25 nmi	1	2	3	4	5
25 to 50nmi	1	2	3	4	5
Over 50 nmi	1	2	3	4	5

Part 3

Participants ranked the importance or relevance of 14 assessment cues (Cargo was inadvertently omitted) and three other items: Origin, Superstructure Type, and Platform Type. They ranked 17 items. The ranking was from 1 (item most relevant to determining threat) to 17 (item least relevant to determining threat). The rankings were a rough index to each cue's relative weight. Relative weights are used in the assessment algorithm and are derived empirically (see Liebhaber, Kobus, and Smith, 2000).

Part 4

The final questions asked participants to identify from whom they received information, and to whom they passed information. The purpose was to better understand the flow of data and the functional relationships within CIC. Flow data are important for identifying and understanding the process of threat assessment and course of action selection. The data show the communication pathways used most often and highlight potential areas where enhanced displays may help reduce communication gaps and task interruptions.

2.3 PROCEDURE

Each participant was briefed about the study's purpose. All participants then filled out a written questionnaire that included questions about their military experience and track threat ratings. The questionnaire took about 15 minutes to finish.

3. RESULTS

The baseline threat levels for categories of tracks are reported first, followed by the relationship between cue data and corresponding perception of threat, and then cue rankings and information flow.

3.1 BASELINE THREAT RATINGS FOR SHIPS

Part 1 of the questionnaire asked participants to rate the perceived threat of tracks in standard categories (e.g., Friend, Enemy, etc.). Table 1 shows mean ratings. Participants responded to all questions in Part 1, but Table 1 shows only selected categories. Threat ratings in the littoral environment tended to be higher than in the open ocean environment. This finding was consistent with data from the air threat assessment studies (Liebhaber, Kobus, and Smith, 2000). The values in Table 3 are the baseline or default threat levels for surface tracks in these categories.

Table 3. Mean threat rating in each operational environment.

	Littoral		Open Ocean	
Type or Category	Mean	Stdev	Mean	Stdev
Flag/Origin				
Friend	2.11	1.27	1.78	0.97
Unknown	2.89	1.36	2.89	1.27
Hostile	4.22	0.83	4.00	0.87
Hull Type				
Type 1	2.63	1.69	2.14	1.46
Military Ship				
Carrier	3.33	1.32	3.33	1.50
Patrol/Escort	3.67	0.87	3.44	1.01
Service Craft	2.00	1.22	1.67	0.71
Other Auxiliary	2.00	1.22	1.67	0.71
Commercial/Private Ship				
Sealift	1.89	1.27	1.56	0.73
Fishing	1.89	1.27	1.56	0.73

3.2 PERCEPTION OF THREAT

Participants estimated changes to the baseline threat level for 15 cues. An example for Range was shown above. Participants responded on a scale from 1 (lower threat level greatly) to 5 (raise threat level greatly). Their mean responses were converted to threat level change ratings (TCRs). TCRs ranged from -2 (lower threat level greatly) to 0 (no change to threat level) to +2 (raise threat level greatly). The ratings were converted to index the magnitude of change and the rise or fall in baseline threat level. They are also easily incorporated into the threat assessment algorithm. Participants responded to all questions on the questionnaire; however, Table 4 shows only selected TCRs for each cue in each environment. As an example, a ship that is slowing down in a littoral environment will increase in threat rating by 0.44.

Table 4. Selected TCRs in each operational environment.

Cues with Data Values	Littoral	Ocean
Speed		
Steady	-0.22	-0.22
Decrease	0.44	0.33
Heading		
Steady/Closing	1.44	1.33
CPA		
Under 1 nmi	1.78	1.78
Recent history		
On standard patrol/route	0.50	0.44
Unknown	0.56	0.67
Range		
Under 5 nmi	1.56	1.44
Over 50 nmi	-1.00	-0.89
Cargo		
Possible contraband	0.89	0.89
Number of vessels		
Single contact	0.11	0.11
Sea Lane		
On/Following	-0.11	0.00
Emission Sensing Monitor (ESM)		
No Emitter	0.67	0.67
Coordinated Activity		
Training/Exercise	0.33	0.33
Voice Communication with Track		
Have Communication with Track	0.67	0.67
Own Support in Area		
DCA or Helicopter Available	0.56	0.56
Destination		
Unknown	0.67	0.67
Weapon Envelope		
Outside	-0.33	-0.33
Regional Intelligence		
No hostile activities known	0.56	0.44

3.3 RELATIVE IMPORTANCE OF CUES

Participants (N = 8) were asked to rank the cues in relative importance to the assessment of threat. Origin, Superstructure Type, and Platform Type were added to the list. There were 17 items to rank. (Note: Cargo was inadvertently not included.) The number 1 was assigned to the cue with the highest relative importance. The number 17 was assigned to the cue with the lowest relative importance. Data from eight participants were tallied. One participant was dropped because of outlying values.

Calculating the number of times each cue was assigned to a particular rank (or position), and then dividing that number by the number of participants computed a ranking across all subjects (the mean proportion that each cue appeared in a given position). For example, Table 3 shows ESM rankings. Two participants ranked ESM first (Rank = 1), four participants ranked it third, and one participant each ranked it eighth and ninth. Dividing by 8 gave the mean proportion in each position (Table 5).

Table 5. Example of rank assignments using ESM.

Rank	1	2	3	4	5	6	7	8	9
Number of times ESM was assigned to a given Rank by the participants	2	0	4	0	0	0	0	1	1
Mean Proportion	0.25	0.00	0.50	0.00	0.00	0.00	0.00	0.13	0.13

The cue with the highest mean proportion in each position was the most representative cue at that position. Table 6 shows the rankings. The list has duplicate entries because the rankings for some cues were spread across many ranks. A cue's position in the list determines its importance, from 1 (highest) to 17 (lowest). Table 7 lists the cues without duplicate entries. Duplicates were removed by keeping only the highest ranked position for any cue.

Table 6. Relative importance of cues (with duplicates).

Rank	Mean Proportion	Cue
1	0.25	Platform/Wpn Env/ESM
2	0.38	Origin-Flag
3	0.50	ESM
4	0.38	Weapons envelope
5	0.25	Range
6	0.38	Heading
7	0.25	CPA/Speed
8	0.25	CPA
9	0.25	Number of vessels
10	0.25	Own support in area
11	0.25	Destination
12	0.25	Heading/History/Coordinated Activity/Voice Communications
13	0.13	CPA/Range/Number/Sea Lane/Coordinated Activity/Voice communications/Own support/Other intelligence
14	0.25	Superstructure/Voice Communications/Destination
15	0.38	Sea lane
16	0.50	Superstructure type
17	0.38	Other intelligence

Table 7. Relative importance of cues (without duplicates).

Rank	Cue
1	Platform/Weapon Envelope/ESM
4	Origin-Flag
5	Range
6	Heading
7	CPA/Speed
9	Number of vessels
10	Own support in area
11	Destination
12	History/Coordinated Activity/Voice communication
15	Sea Lane/Other intelligence
17	Superstructure Type

3.4 INFORMATION FLOW IN CIC

Data were collected on information flow among watch standers within CIC. Participants were asked to list their most recent SUW watch station. They then identified other watch stations that were sending and receiving information. Figure 1 shows the flow of information that participants reported. In this study, participants' most recent watch station experience was as Antisurface Warfare Coordinator (ASUWC), Antisubmarine Tactical Air Controller (ASTAC), Antisubmarine Warfare Coordinator (SWC), Electronic Warfare Supervisor (EWS), and Combat Systems Coordinator (CSC). The arrows show the direction of communication (one- and two-way). The dashed lines mean that only one participant mentioned the communication channel. Otherwise, line thickness represented the number of times a participant mentioned a connection; thicker lines mean higher frequency.

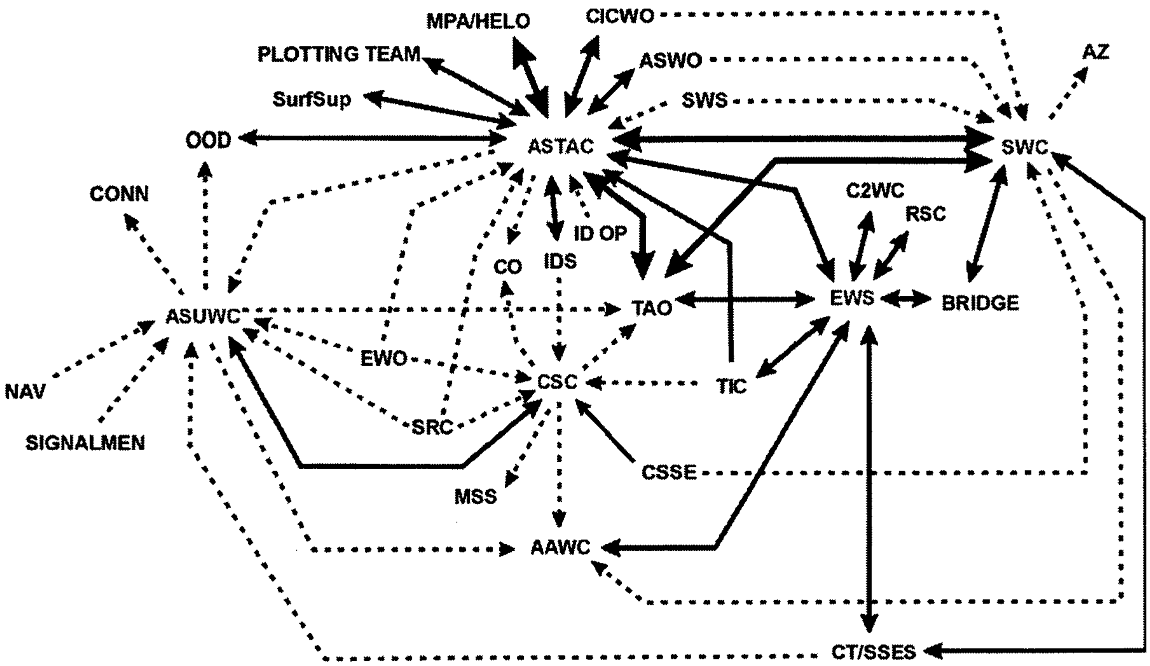

Figure 1. Surface warfare information flow.

4. SURFACE THREAT ALGORITHM

Appendix D describes a preliminary flowchart for a rule-based, surface threat algorithm. The algorithm is based on the air threat algorithm that was developed after a series of empirical and observational studies of U.S. Navy air defense personnel (Liebhaber, 2001). The algorithm incorporates and analyzes relevant data that were collected for this study and computes a threat rating for each surface track.

5. DISCUSSION

Surface Warfare data were collected from highly experienced U.S. Navy personnel. The participants provided baseline threat ratings for many types of ships, their perception of threat for assessment cues, and channels of information flow within CIC. Baseline threat ratings were consistent with the findings from air defense studies (Liebhaber and Smith, 2000; Liebhaber, Kobus, and Smith, 2000). Participants assigned higher threat ratings to ships in a littoral environment as opposed to ships in the open ocean. Threat change ratings showed differences in each operating environment, but the effect was not consistent across all cues. Relative importance of cues was calculated from participants' ratings of threat level change and a preliminary surface threat algorithm was described. The threat and threat change ratings and relative importance will be incorporated into future development of the SUW threat assessment algorithm.

While this study describes the relationship between track cues and changes to threat rating, that information is only part of the SUW algorithm. Work is needed to identify how SUW personnel use the cues to evaluate tracks and specify the relative importance of the cues. These data will be incorporated into the algorithm, enabling it to better capture the process of SUW threat assessment.

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APPENDIX A

SURFACE WARFARE QUESTIONNAIRE

The format of the questionnaire has been slightly modified to fit within this report.

Surface Track Analysis Questionnaire

Introduction

- The purpose of this questionnaire is to gather specific information about the data that you use when you analyze surface contacts.
- Many of the questions are about single pieces of information (e.g., speed, sea lane, etc). We realize that information is not processed in isolation in the real situation. However, we need to understand how individual elements are handled.

Your Background

- What is your current Rank/Rate? ______________
- Deployed Surface Warfare Experience
  - Please indicate the number of years or months you spent in positions where you were directly involved in surface craft ID, threat analysis, or COI/CCOI and COA determination.
  - Answer all that apply, to the best of your recollection.

	At-Sea Experience	
SW Position	**Years**	**Months**
Commanding Officer (CO)		
Tactical Action Officer (TAO)		
AntiSurface Warfare Coordinator (ASuWC)		
Surface Force Track Coordinator (SFTC)		
Surface ID (SID)		
Tactical Information Coordinator (TIC)		
Auxiliary Radar Console Operator (ARC)		
Electronic Warfare Operator (EWO)		
Electronic Warfare Supervisor (EWS)		
Radar System Controller (RSC)		
Other SW positions not listed above		

PART 1: Threat Posed by Different Types Of Ships

- Based on your experience, how threatening, on average, is this type of ship?
- Please circle your answer for each environment.

	"Littoral" Environment					"Open Ocean" Environment				
Origin/Flag/ID	Never	Rarely	Sometimes	Often	Always	Never	Rarely	Sometimes	Often	Always
Friend	1	2	3	4	5	1	2	3	4	5
Unknown, Assumed Friend	1	2	3	4	5	1	2	3	4	5
Unknown	1	2	3	4	5	1	2	3	4	5
Unknown, Assumed Enemy	1	2	3	4	5	1	2	3	4	5
Hostile	1	2	3	4	5	1	2	3	4	5
Superstructure										
Type 1	1	2	3	4	5	1	2	3	4	5
Type 2	1	2	3	4	5	1	2	3	4	5
Type 3	1	2	3	4	5	1	2	3	4	5
Military - Potentially Hostile Vessels										
Carrier	1	2	3	4	5	1	2	3	4	5
Submarine	1	2	3	4	5	1	2	3	4	5
Surface Combatant	1	2	3	4	5	1	2	3	4	5
Patrol/Escort	1	2	3	4	5	1	2	3	4	5
Amphibious Warfare	1	2	3	4	5	1	2	3	4	5
Mine Warfare	1	2	3	4	5	1	2	3	4	5
Special Warfare/Ops	1	2	3	4	5	1	2	3	4	5
Intelligence	1	2	3	4	5	1	2	3	4	5
Oiler	1	2	3	4	5	1	2	3	4	5
Sealift	1	2	3	4	5	1	2	3	4	5
Research	1	2	3	4	5	1	2	3	4	5
Repair/Rescue	1	2	3	4	5	1	2	3	4	5
Service Craft	1	2	3	4	5	1	2	3	4	5
Other Auxiliary	1	2	3	4	5	1	2	3	4	5
Commercial/Private Vessels										
Sealift	1	2	3	4	5	1	2	3	4	5
Research	1	2	3	4	5	1	2	3	4	5
Repair/Rescue	1	2	3	4	5	1	2	3	4	5
Service Craft	1	2	3	4	5	1	2	3	4	5
Fishing	1	2	3	4	5	1	2	3	4	5
Pleasure/Small	1	2	3	4	5	1	2	3	4	5

PART 2: Potentially Threatening Characteristics or Behaviors Of Ships

- Indicate how the following data would CHANGE your estimate of threat.
- Treat each item as if were the only piece of data you received at the moment.
- Each item requires two answers – One each for the following environments:
  - Littoral
  - Open Ocean
- Please answer the questions as accurately as possible.
- We are interested in your at-sea experience, in what has worked for you.

Surface ship behaviors - How would the values below CHANGE your estimate of threat?

	"Littoral" Environment					"Open Ocean" Environment				
Value Ranges	lower greatly	lower a little	no change	raise a little	raise greatly	lower greatly	lower a little	no change	raise a little	raise greatly
Speed										
Speed steady	1	2	3	4	5	1	2	3	4	5
Speed increase	1	2	3	4	5	1	2	3	4	5
Speed decrease	1	2	3	4	5	1	2	3	4	5
Speed of										
under 6 kts	1	2	3	4	5	1	2	3	4	5
6-10 kts	1	2	3	4	5	1	2	3	4	5
10-20 kts	1	2	3	4	5	1	2	3	4	5
over 20 kts	1	2	3	4	5	1	2	3	4	5
Course/Heading relative to Own-Ship										
Steady and closing	1	2	3	4	5	1	2	3	4	5
Steady and opening	1	2	3	4	5	1	2	3	4	5
Turn to closing	1	2	3	4	5	1	2	3	4	5
Turn to opening	1	2	3	4	5	1	2	3	4	5
CPA										
under 1 nm	1	2	3	4	5	1	2	3	4	5
1-5 nm	1	2	3	4	5	1	2	3	4	5
5-15 nm	1	2	3	4	5	1	2	3	4	5
15-25 nm	1	2	3	4	5	1	2	3	4	5
25-50 nm	1	2	3	4	5	1	2	3	4	5
over 50 nm	1	2	3	4	5	1	2	3	4	5
Recent maneuvers/history										
On standard patrol/route	1	2	3	4	5	1	2	3	4	5
Not on standard patrol/route	1	2	3	4	5	1	2	3	4	5
Left port recently	1	2	3	4	5	1	2	3	4	5
Left port a long time ago	1	2	3	4	5	1	2	3	4	5
Many maneuvers/zig-zags	1	2	3	4	5	1	2	3	4	5
Changes course to match own-ship movements	1	2	3	4	5	1	2	3	4	5
Unknown	1	2	3	4	5	1	2	3	4	5

Value Ranges	"Littoral" Environment					"Open Ocean" Environment				
	lower greatly	lower a little	no change	raise a little	raise greatly	lower greatly	lower a little	no change	raise a little	raise greatly
Range/Distance from Own-Ship										
Under 5 nm	1	2	3	4	5	1	2	3	4	5
5-25 nm	1	2	3	4	5	1	2	3	4	5
25-50 nm	1	2	3	4	5	1	2	3	4	5
Over 50 nm	1	2	3	4	5	1	2	3	4	5
Within Vital Area	1	2	3	4	5	1	2	3	4	5
Within CIE Area	1	2	3	4	5	1	2	3	4	5
Within potential weapon range	1	2	3	4	5	1	2	3	4	5
Cargo										
Stacked pallets	1	2	3	4	5	1	2	3	4	5
Arms/Ammunition	1	2	3	4	5	1	2	3	4	5
Refugees	1	2	3	4	5	1	2	3	4	5
Possible contraband	1	2	3	4	5	1	2	3	4	5
Number of vessels										
Unknown	1	2	3	4	5	1	2	3	4	5
Single contact	1	2	3	4	5	1	2	3	4	5
3 - 5	1	2	3	4	5	1	2	3	4	5
Over 5	1	2	3	4	5	1	2	3	4	5
Sea Lane/Traffic Lane										
On/following	1	2	3	4	5	1	2	3	4	5
Near	1	2	3	4	5	1	2	3	4	5
Off	1	2	3	4	5	1	2	3	4	5
ESM/Radar Emitter										
No emitter	1	2	3	4	5	1	2	3	4	5
Emitter: I-Band	1	2	3	4	5	1	2	3	4	5
Emitter: Non I-Band	1	2	3	4	5	1	2	3	4	5
Coordinated Activity										
Training/exercise	1	2	3	4	5	1	2	3	4	5
Hiding	1	2	3	4	5	1	2	3	4	5
Track in comm. with air, surface, or land asset(s)	1	2	3	4	5	1	2	3	4	5
Possibly providing targeting	1	2	3	4	5	1	2	3	4	5
Voice communication with track										
None	1	2	3	4	5	1	2	3	4	5
Have comm. with track	1	2	3	4	5	1	2	3	4	5
Own support in area										
None available	1	2	3	4	5	1	2	3	4	5
Surface available	1	2	3	4	5	1	2	3	4	5
DCA or Helo available	1	2	3	4	5	1	2	3	4	5

Value Ranges	"Littoral" Environment: lower greatly	lower a little	no change	raise a little	raise greatly	"Open Ocean" Environment: lower greatly	lower a little	no change	raise a little	raise greatly
Destination of track										
Headed towards standard port	1	2	3	4	5	1	2	3	4	5
Not headed towards std port	1	2	3	4	5	1	2	3	4	5
Unknown	1	2	3	4	5	1	2	3	4	5
Weapon Envelope of track (Potential or Known)										
Outside	1	2	3	4	5	1	2	3	4	5
Just outside	1	2	3	4	5	1	2	3	4	5
Just inside	1	2	3	4	5	1	2	3	4	5
Inside	1	2	3	4	5	1	2	3	4	5
Regional Intelligence										
Recent activity in/near port	1	2	3	4	5	1	2	3	4	5
Military exercises in area	1	2	3	4	5	1	2	3	4	5
No military exercises known	1	2	3	4	5	1	2	3	4	5
No hostile activities known	1	2	3	4	5	1	2	3	4	5
Anti US protests in region	1	2	3	4	5	1	2	3	4	5
Economic summit planned	1	2	3	4	5	1	2	3	4	5
Peace summit planned	1	2	3	4	5	1	2	3	4	5

Part 3: Rank data in order of relative importance to determination of threat

- Begin with #1 as MOST important

______ Origin/Flag

______ Superstructure Type

______ Platform Type

______ Speed

______ Course/Heading (in-/out-bound)

______ CPA

______ Recent Maneuvers/History

______ Range/Distance from Own-Ship

______ Number of Vessels

______ Sea Lane/Traffic Lane

______ ESM/Radar Emitter

______ Coordinated Activity

______ Voice communication with track

______ Own support in area

______ Destination

______ Weapons envelope

______ Other intelligence

______ Other: ____

PART 4: Surface Warfare Information Flow

- Write your position in the box in the middle of the page.
- On the lines next to your position, list the positions that you receive information from and send information to.

List the position(s) that you
GET information from:

List the position(s) that you
GIVE information to:

Your most recent ASuW position

THANK YOU. You are finished!

APPENDIX B

SURFACE WARFARE CIC WATCH STATIONS

Participants indicated that they had experience in an average of 3.3 years at the watch stations described in Table B-1.

Table B-1. Surface warfare CIC Watch Stations.

Term	Description
ARC	Auxiliary Radar Console Operator
ASTAC	Antisubmarine Tactical Air Coordinator: Directs operations of ASW aircraft
ASUWC	Anti-Surface Warfare Coordinator: Controls the surface warfare team, directs and integrates track assessment, monitoring, and engagement
CSC	Combat System Coordinator: Responsible for the operation of the AEGIS combat systems
EWO/EWS	Electronic Warfare Operator/Supervisor: Maintains the sensor-based electronic emissions and warfare situation.
RSC	Radar System Controller
SID	Surface ID
SFTC	Surface Force Track Coordinator
SWS	Surface Watch Supervisor
TAO	Tactical Action Officer: Directs and coordinates responses to threats with all warfare coordinators
TIC	Tactical Information Coordinator: Controls sensor operators and data links

APPENDIX C

SURFACE THREAT ASSESSMENT CUES

Table C-1 lists surface threat assessment cues in alphabetical order.

Table C-1. Surface threat assessment cues.

Cue	Description
Cargo	Type of cargo ship is, or may be, carrying (includes people).
Coordinated activity	Track is communicating with, or nearby, other tracks or other assets.
CPA	Closest Point of Approach: Estimated distance that track will pass by own ship if the track and own ship remain on their current courses.
Destination	Probable destination of the ship.
ESM/Radar emission	Electronic Support/Measures: Electronic emissions from the track (typically indicates the type of radar system the track is using).
Heading	Direction ship is traveling relative to own ship (i.e., opening or closing).
Number of vessels	Number of ships in close proximity.
Own Support	Availability of nearby friendly ships or patrol aircraft (DCA or HELO)
Range/Distance	The track's distance from own ship.
Recent history	The track's recent maneuvers.
Regional Intelligence	Geopolitical and military situation in the region the ship is operating.
Sea Lane	A published, typical, or otherwise known route of travel.
Speed	Approximate speed or an indication of change (e.g., increasing).
Voice communication with track	Indicates if ownship, or nearby friendly asset, has communicated with the track.
Weapon envelope	The track's position with respect to its estimated weapons envelope (e.g., within).

APPENDIX D

SURFACE THREAT ALGORITHM SPECIFICATIONS

A preliminary rule-based, surface threat algorithm is described below. It is based on the air threat algorithm that was developed after a series of empirical and observational studies of U.S. Navy air defense personnel (Liebhaber, 2001). In its current form, the algorithm incorporates and analyzes relevant data (as identified by U.S. Navy surface warfare experts) and computes a threat rating for each surface track.

SURFACE THREAT ALGORITHM DETAIL

Processing is divided into three stages. Baseline threat level is computed in stage one from ID and Platform Threat Ratings (see Table 1). Threat assessment is then conducted by evaluating each of the cues in turn, and adjusting threat level accordingly. Threat level is adjusted by adding or subtracting Threat Change Ratings from Table 2.

Critical, or high weight, cues are evaluated first; in stage two. Critical cues are those the cues most often used by experienced ASuW personnel. The best guide at this time is the indication of relative importance in Table 5. Remember that importance is approximated by list position. Cues with the highest weight are the critical cues, however, the high/low cutoff value must be empirically determined. In stage three, the remaining cues are evaluated only if exceptions are encountered in one or more of the critical cues. Exceptions are data values that are unexpected or atypical (e.g., increasing speed for a nearby small ship). Their values must also be empirically determined. Exception Score is used to determine whether or not to evaluate additional cues beyond the critical cues. It is initialized to zero. When the algorithm processes a cue value that is an exception, the weight of that cue is subtracted from Exception Score. If the value of Exception Score is less than zero after all of the critical cues have been processed, then the algorithm will process additional cues. The weights of the additional cues are added to Exception Score (unless they were an exception, too). The assumption is that an unexpected value for a given cue implies a loss of information. That loss is captured in the algorithm by subtracting the weight of that cue from the Exception Score. Additional cues must be processed until that loss is made up.

Stage 1. Compute baseline threat level

1a. *Baseline Threat Rating* = *ID Threat Rating* + *Platform Threat Rating*

- Example: Baseline Threat Level of an Unknown (2.89) Military Patrol/Escort (3.67) ship is 2.89 + 3.67 = 6.56

Stage 2. Adjust threat rating using the critical track cues

For each critical cue do

2a. Get data value for the current cue

2b. New *Threat Rating* = Old *Threat Rating* ± *Threat Change Rating* for current data value

- Note: When the first cue is evaluated, Old Threat Rating equals the Baseline Threat Rating.
- Example: Threat Rating of an Unknown Patrol/Escort (6.56) that is slowing down in a littoral environment (0.44) is 6.56 + 0.44 = 7.00.

2c. IF Value for current cue is an exception

THEN New *Exception Score* = Old *Exception Score* - *Weight* for current cue

Stage 3. Adjust threat rating using additional cues, if necessary

While *Exception Score* < 0 do

3a. Get data value for the current cue

3b. New *Threat Rating* = Old *Threat Rating* ± *Threat Change Rating* for current data value

3c. New *Exception Score* = Old *Exception Score* + *Weight* for current cue

3d. IF Value for current cue is an exception

THEN New *Exception Score* = Old *Exception Score* - *Weight* for current cue

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This report discusses the results of a preliminary investigation of cues (e.g., speed, range, etc.) that experienced surface warfare personnel use to assess the threat level of nearby surface ships. Data were collected from experienced U.S. Navy surface warfare watch standers within a Combat Information Center (CIC) on an Aegis-equipped ship. The data were incorporated into an outline of an algorithm for surface threat assessment.

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